DIAMETER-WEIGHT RELATIONSHIPS FOR JUNIPER FROM WET AND DRY SITES

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ABSTRACT.— Height-diameter (basal or canopy) relationships for *Juniperus scopulorum* trees taken from wet and dry sites were quite different, but total aboveground weight-diameter relationships for trees taken from the two sites did not differ. It is shown that log total weight (kg) = approximately 1.7 + 2.26 log basal diameter (cm) = − 2.55 + 2.98 log canopy diameter (cm). Though the first relationship ($r^2 = 0.98$) is stronger than the second ($r^2 = 0.80$), the canopy diameter-weight relationship may be useful for estimating tree weights from aerial photos. Root-shoot ratios for wet site trees 5, 12, and 31 cm in basal diameter were 37, 27, and 26 percent, respectively.

Linear dimensions are often well correlated with plant biomass (e.g., Kira and Shidei 1967, Weaver and Forcella 1977) and are therefore useful in estimating plant biomass. Basal diameter-weight relationships for many Rocky Mountain trees (Brown 1976, Weaver and Forcella 1977) and shrubs (Brown 1976) have been developed. Crown diameter-weight relationships for several Rocky Mountain shrubs are presented by Weaver (1977); this dimension may be especially useful for low-multistemmed shrubs or for trees seen in aerial photographs.

Because diameter-weight relationships are especially useful if they are general, it is desirable to test for generality by comparing diameter-biomass relationships of individuals of one species from different habitats and exhibiting different life forms. *Juniperus scopulorum* Sarg. is a good test species because (1) it occupies both wet and dry sites, (2) it has a shorter and fuller form on dry than on wet sites, and (3) regression lines should be useful to managers throughout the Rocky Mountain area occupied by the tree (Little 1971).

METHODS

Thirteen juniper trees were felled in October 1980. They stood immediately east of the Headwaters of the Missouri State Park, Gallatin County, Montana. Seven of these trees came from a bottomland site covered by a *Populus trichocarpa* T&G—*Juniperus scopulorum* forest. The six remaining trees came from adjacent dry hills covered by a *Juniperus scopulorum-Bouteloua gracilis* (HBK) Lag. ex Steud. woodland.

The dry weight of each tree was determined by the following procedure. The tree was felled and divided into portions with diameters of 0–1, 1–5, 5–10, and greater than 10 cm. These were weighed wet. Samples of material representative of each size were taken, weighed wet, and weighed again after drying to constant weight at 60 C. Dry weight/wet weight ratios for the 0–1, 1–5, 5–10, and 10+ cm size classes were 61, 56, 61, and 61 percent on the dry site and 56, 54, 56, and 53 percent on the wet site. The dry weight of each tree was estimated by multiplying wet weights of each portion by its dry weight/wet weight ratio and summing across portions.

The contribution of photosynthetic organs to the 0–1 cm class was estimated by separating green leaves and twigs from dried samples, weighing, and expressing as a percentage of the 0–1 cm total. The density of dry trunk wood was estimated by dividing sample weights by volumes (about 50 cc) estimated by displacement of water.

The method used to test for the equality of regression lines in both wet and dry sites was to complete three separate regressions using data from, (1) wet sites only, (2) dry sites

only, and (3) wet and dry sites combined. Using the symbol SS_i for the residual sum-of-squares in these regressions, the F-statistic for testing equal of regression lines in the two kinds of sites is

$$F = \frac{(SS_3 - SS_1 - SS_2)}{(SS_1 + SS_2)/(N_1 + N_2 - 4)} .$$

This value is compared to entries in an ordinary F table at 2 and $N_1 + N_2 - 4$ degrees of freedom. Although this procedure does not appear in statistical methods texts, it is a simple application of the basic theory for testing linear models (Graybill 1976). The new procedure is a reformulation of the analysis of covariance problem to handle simultaneously a test for both equality of slopes and intercepts (Snedecor 1980).

RESULTS AND CONCLUSIONS

Although the general climate of our two study sites was nearly identical, their environments were quite different. The climate of the Headwaters of the Missouri areas is dry-continental with an average annual precipitation of 299 mm, average January temperatures of –1 C maximum to –12 C minimum, and average July temperatures of 28 C maximum to 11 C minimum (USDC 1978, Trident). The dry site trees came from a *Bouteloua gracilis – Juniperus scopulorum* savannah typical of upland sites of the region. The wet site trees came from a riverside site dominated by old *Populus trichocarpa* trees; they undoubtedly experienced less water stress than the dry site trees due to the site's high water table and shelter from wind and radiation provided by the cottonwoods.
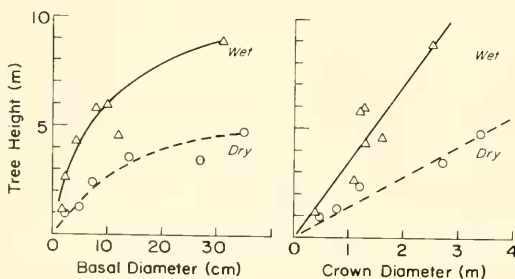
Trees from different environments are expected to have different forms, and indeed they do. (1) Though crown diameter at both sites is linearly related to tree height, at a given crown diameter, dry site trees are only half as tall as wet site trees (Fig. 1). We therefore describe dry site trees as 'broadly conical to hemispheric' and wet site trees as 'spindly.' (2) At both sites supporting structure (basal diameter) increases logarithmically with tree height as is mechanically necessary (Alexander 1971). Still, at a given height, trees of dry sites have bases almost twice as thick as those of wet sites. (3) Because short trees of dry sites and taller trees of wet sites have similar quantities of small leafy twigs per unit of canopy breadth or basal diameter (Table 1), the trees of dry sites have denser foliage (more twigs per vertical meter) than the trees of wet sites. Despite larger reddish heartwood deposits, the density of dry site trunk wood (0.49 ± 0.06 SE g/cc) is not significantly greater than that of wet site wood (0.42 ± 0.05 SE g/cc n = 3, p = 0.05).

Despite the form differences just described, trees of both sites have essentially identical biomasses per unit of basal diameter or canopy diameter. This is demonstrated visually with plots of untransformed total biomass data against tree size (Fig. 2). Regressions of log total aboveground weight (kg) and log
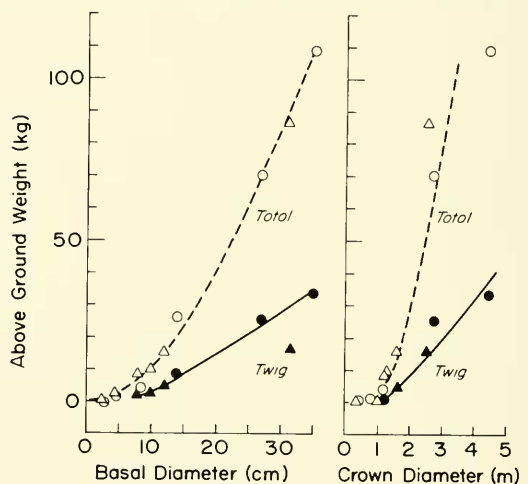

Fig. 2. Aboveground weight-diameter relationships are similar for trees grown on wet (△) and dry (○) sites. Dashed line summarizes total aboveground weight data and the solid line summarizes twig (0–1 cm diameter) weight data.

Fig. 1. Wet (△) and dry site (○) tree height-diameter relationships for both basal and canopy diameters differ significantly.

Table 1. The relationship between tree diameter and aboveground tree weight is shown with regressions of the form log weight (kg or g) = a + b log diameter (cm).

Site	Intercept (a)	Slope (b)	r^2	N	F[1]
		Total weight (kg) basal diameter (cm)			
Wet	1.78	2.21	0.98	7	
Dry	1.55	2.37	0.98	6	
Pooled	1.70	2.26	0.98	13	0.72
		Twig weight (g) basal diameter (cm)			
Wet	1.64	1.78	0.98	7	
Dry	1.60	1.98	0.98	6	
Pooled	1.59	1.91	0.97	13	2.67
		Total weight (kg) canopy diameter (cm)			
Wet	−3.56	3.46	0.80	7	
Dry	−1.94	2.70	0.98	5	
Pooled	−2.55	2.98	0.88	12	0.54
		Twig weight (g) canopy diameter (cm)			
Wet	−2.59	2.75	0.79	7	
Dry	−1.32	2.26	0.97	5	
Pooled	−1.93	2.48	0.85	12	1.19

[1] F testing for difference between wet and dry site regressions. Critical points are 95% = 4.26, 90% = 3.01, 75% = 1.62.

twig biomass (g) against tree size (cm) are summarized in Table 1; in no case did populations differ significantly. Separation of scales from leafy twigs shows that 75 ± 3 and 59 ± 6 SE percent of the leafy twig weight is leaf on dry and wet sites respectively; with six samples from each tree the difference is not statistically significant at P = 0.05. Root-shoot ratios for bottomland trees 5, 12, and 31 cm in diameter were 37, 27, and 26 percent, respectively. Root-shoot ratios appear to generally decline with increasing tree size (Weaver 1974).

Our observation that tall trees and short trees of the same diameter have the same weight is both counter-intuitive and useful. Even if dry site wood is slightly more dense than wet side wood, density differences are insufficient to explain this observation. Instead, the biomass appears to be distributed as if there were a fixed amount of photosynthate per internode which is devoted to diameter growth if it is not expended in height growth. Such allocation on the dry site could be due to adequate light combined with trunk thickening induced by wind stress, while on the wet site it might be due to shade induced etiolation combined with low wind stress (Kramer and Kozlowski 1979, Zimmerman and Brown 1971). Regardless of its cause, the relationship is useful because it suggests that we may apply diameter-biomass relationships developed on one site to other, environmentally dissimilar sites.

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